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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 November 2004 (18.11.2004)

PCT

(10) International Publication Number
WO 2004/099685 A1

(51) International Patent Classification[7]: F25B 27/00, B01D 53/26, E03B 3/28, F03D 9/00

(21) International Application Number: PCT/NL2004/000322

(22) International Filing Date: 12 May 2004 (12.05.2004)

(25) Filing Language: Dutch

(26) Publication Language: English

(30) Priority Data:
1023386 12 May 2003 (12.05.2003) NL

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

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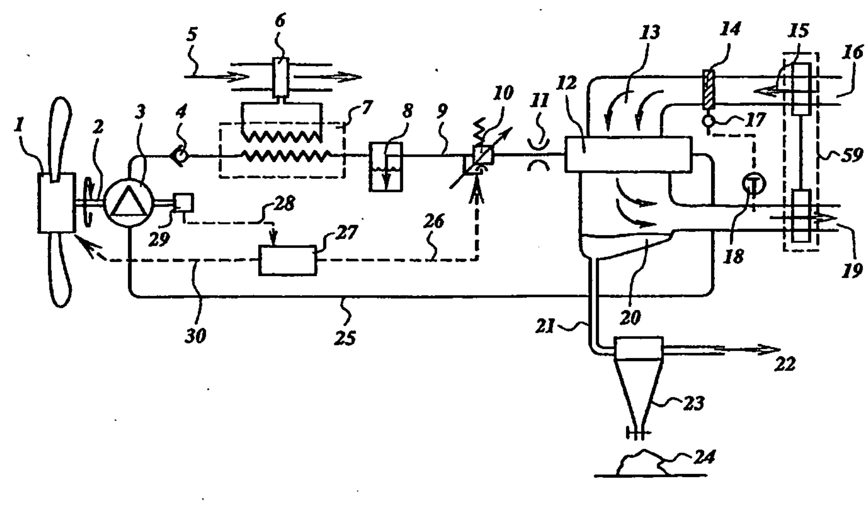
(54) Title: DEVICE FOR CONDENSING WATER VAPOUR



(57) Abstract: The invention relates to a device for condensing water vapour, having a compressor (3) driven by a turbine (1), a condensation tank (8), an evaporator (12), a pressure-reducing valve (10) in a refrigerant line between the condensation tank and the evaporator, and a passage (13) for transporting water vapour which is to be condensed to the evaporator (12). There are first control means (10, 11, 80) for increasing the pressure in the condensation tank (8) as the flow of refrigerant to the evaporator (12) increases, and second control means (14, 17, 18) for controlling the quantity of water vapour transported to the evaporator (12) as a function of the temperature of the evaporator (12).

WO 2004/099685 A1

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

Device for condensing water vapour

The invention relates to a device in accordance with the preamble of Claim 1. A device of this type is known from application FR 2833044, which was not published before the priority date of the present application. This document does not disclose how the settings of the device should be changed on the basis of changes in the wind speed and air humidity in order to make the most efficient use of the device. To avoid this drawback, the device is designed in accordance with the characterizing clause of Claim 1. As a result, the pressure to be generated by the compressor is increased by the first control means in the event of an increasing flow to the evaporator, i.e. in the event of an increasing output from the compressor. As a result, the turbine is subject to more resistance and more power is taken off from the turbine. As a result, the rotational speed of the turbine will only increase enough for the power supplied by the turbine to correspond to the power taken up by the compressor. On account of the fact that the quantity of refrigerant flowing to the evaporator can vary with the power delivered by the turbine, the cooling capacity of the evaporator also varies. The cooling capacity is delivered to water vapour and/or air flowing through the evaporator. The condensation of the water vapour is preferably carried out at a more or less constant temperature, and the cooling capacity required to cool the air and/or water vapour and for the condensation is dependent on the temperature and humidity of the air. Adjusting the quantity of air and/or water vapour as a function of the temperature of the evaporator allows optimum condensation to be achieved, with the result that the second control means change the quantity of water vapour and/or air flowing through the evaporator as a function of the temperature of the evaporator.

According to a refinement, the device is designed in

accordance with Claim 2. Direct measurement of the flow of refrigerant to the evaporator results in direct coupling to the use of refrigerant and the pressure, with the result that the control is not affected to such an extent by the yield of the compressor or the efficiency of the cooler.

According to a refinement, the device is designed in accordance with Claim 3. This results in simple operation of the pressure-reducing valve, which is independent of the electrical power supply and the like..

According to a refinement, the device is designed in accordance with Claim 4. The use of a sensor-controlled air valve allows simple control of the temperature of the evaporator.

According to a further improvement, the device is designed in accordance with Claim 5. This results in simple actuation of the air valve which is independent of the electrical power supply and the like.

According to a refinement, the device is designed in accordance with Claim 6. This makes it easy to remove dust entrained with the air from condensed water vapour.

According to a refinement, the device is designed in accordance with Claim 7. This increases the capacity of the device in a simple way.

According to a refinement, the device is designed in accordance with Claim 8. This allows drinking water to be made from salt water.

According to a further refinement, the device is designed in accordance with Claim 9. This increases the capacity for converting salt water into drinking water.

According to a further refinement, the device is designed in accordance with Claim 10. The result is an installation which is simple to maintain.

In accordance with a further refinement, the device is designed in accordance with Claim 11. This further improves the possibilities for using the device without power.

The invention is explained below on the basis of a number of exemplary embodiments and with the aid of a drawing, in which:
Figure 1 shows a diagrammatic view of a process for condensing water vapour which is present in outside air,
Figure 2 shows a diagrammatic view of a process for evaporating and condensing water,
Figure 3 shows a diagrammatic drawing illustrating a device for use in the process shown in Figure 1, and
Figure 4 shows a diagrammatic drawing illustrating a device for use in the process shown in Figure 2, and
Figure 5 shows a diagrammatic drawing of an alternative embodiment of a pressure-control valve with restriction.

Figure 1 shows a compressor 3 which is coupled via a shaft 2 to a wind turbine 1, it being possible for the wind turbine 1 to have a variable rotational speed which can be measured by a rotational speed measuring device 29. As an alternative to a wind turbine 1, the compressor 3 can also be driven in a comparable way by a water turbine. The compressor 3 is connected to a condensation tank 8 by a refrigerating-liquid line 9 via a nonreturn valve 4 and a cooler 7. The compressor 3 is suitable for compressing refrigerant of a known composition which, after cooling, can condense in the condensation tank 8. The cooler 7 is coupled to a heat exchanger 6, through which an air stream 5 can be

passed in order to dissipate the heat produced by the compression of the refrigerant. It is possible for the air stream 5 to be generated by a fan. If appropriate, the condensation tank 8 forms part of the cooler 7.

The refrigerant which has been condensed in the condensation tank 8 can flow to an evaporator 12 via a pressure-control valve 10 and a restriction 11. The pressure-control valve 10 may optionally be designed with a fixed setting, so that it is ensured that there is always sufficient pressure in the condensation tank 8 and the compressed refrigerant is condensed to form liquid. In an alternative embodiment, the pressure set by the pressure-control valve 10 in the condensation tank 8 is variable and is preferably dependent on the rotational speed of the wind turbine 1. In that case, the rotational speed measuring device 29 emits a speed signal 28 to a control system 27. The control system 27 is designed in such a manner that in the event of the rotational speed increasing the pressure in the condensation tank 8 is increased, and therefore so is the pressure to be generated by the compressor 3. This means that as the rotational speed of the wind turbine 1 increases, it has to deliver an increasing torque, which is possible on account of the fact that the rotational speed rises as a result of the increase in wind. If appropriate, it is also possible for the wind speed to be measured directly as an alternative to the rotational speed.

If the rotational speed delivered by the wind rises above a settable value as a result of a further increase in wind, the control system can adjust the wind turbine 1, via a signal 30, in such a manner that the torque delivered to the compressor 3 does not rise further and the rotational speed of the wind turbine 1 does not increase further. The liquid refrigerant flowing into the evaporator 12 via the restriction 11 is evaporated in the evaporator 12 to form gas. The

heat required for this purpose is extracted from the air flowing through the evaporator 12 via a feed passage 13. The air passes as outside air 15 via a feed opening 16 and an air-control valve 14 to the feed passage 13 of the evaporator 12. The refrigerant, which has been expanded to form a gas in the evaporator 12, is returned to the compressor 3 via a gas line 25. The air is cooled in the evaporator 12, with water vapour which is present in the air being condensed to form condensate 20. The cooled and dry air returns to the environment via an air discharge 19. The quantity of air flowing through the evaporator 12 is adapted to the cooling capacity of the evaporator 12, which is dependent on the quantity of refrigerant which has been compressed by the compressor 3. For this purpose, a temperature sensor 18, which controls a control drive 17 of the air-control valve 14, is positioned in the air discharge 19. Increasing or reducing the supply of air to the evaporator 12 causes the temperature at the air discharge 19 to be more or less constant, for example 4 - 7° Celsius, with most of the water vapour which is present in the air having been condensed to form condensate 20.

In view of the above, it will be clear that the process is preferably used in areas where the temperature is significantly higher than 4 - 7° Celsius for a significant proportion of the day. There are also features which ensure that the wind turbine 1 comes to a standstill when the temperature of the outside air 15 and/or the temperature measured by the temperature sensor 18 becomes too low or approaches freezing point.

The condensate 20 is collected and passed to a dust separator 23 via a condensate discharge 21. Water and solids are separated in the dust separator 23, and the water, which is suitable for use as drinking water, is discharged via a water discharge 22, and solids which have been collected are periodically removed from the

dust separator 23 and discharged as solids 24. The quantity of solids collected in the dust separator 23 can be limited, inter alia, by positioning the feed opening 16 high above ground level or providing the feed opening 16 with dust filters, which may be mechanically cleanable.

The process shown does not show any forced circulation of air through the evaporator 12, since it can be assumed that this will be produced automatically through favourable positioning of the feed opening 16 and the air discharge 19 if the feed opening 16 is positioned above the air discharge 19, on account of the cooling of the air. If appropriate, a fan can be provided.

To improve the efficiency of the process, it is possible to add a heat exchanger 59, in which case the outside air 15 is precooled in the vicinity of the feed opening. The heat is in this case dissipated by heating the air in the vicinity of the air discharge 19. The heat exchanger 59 may in this case be designed as two air-liquid heat exchangers with a circulation pump for the liquid, or as a rotary body which has air flowing through it at the air discharge 19 so that it is cooled, and which body, as it rotates further, has outside air 15 flowing through it, cools the air which has flowed through it and then heats it again.

It will be clear to the person skilled in the art that an electronic control system can be selected to control the process. It is also possible to use a simpler control system, in which case, for example, the rotational speed measuring device 29 is designed as a mechanically acting regulator which is coupled to the pressure-control valve 10 and the wind turbine 1. The temperature sensor 18 can also adjust the air-control valve 14 without using the electronic control, for example by virtue of the temperature sensor 18 and the

control drive 17 being connected by a pressure line. Temperature changes cause the volume of a medium which is present there to change, and this change in volume is transmitted via the pressure line to the control drive 17, which adjusts the control valve 14 as a result. If appropriate, the wind turbine 1 is controlled without the use of electronics. The abovementioned measures allow the process to be used in areas without electricity facilities, and the device can be used at many locations, even where there is no water, to make drinking water.

Figure 2 shows a process used to obtain water through evaporation and condensation, by means of which, for example, drinking water can be made from salt water. The condensation of water vapour is carried out in a similar way to that described above, with the aid of an evaporator 12 in which liquid refrigerant evaporates. The evaporator 12 is positioned in a reduced-pressure space 41. In the reduced-pressure space 41, there is a receptacle 38 filled with water 37. With the aid of a vacuum pump 42, a vacuum can be applied in the reduced-pressure space 41, such that the water 37 starts to evaporate (boil) at low temperature. The water vapour which is formed flows through the air-control valve 14 to the evaporator 12 and condenses to form condensate 20. The condensate 20 is pumped via a nonreturn valve 44 through a discharge pump 43 to the users for storage. The temperature downstream of the evaporator 12 is kept at a more or less constant value of 4 - 7° Celsius by controlling the air-control valve 14.

The water 37 is kept at a constant level in the receptacle 38 by a level switch 36 which actuates a valve 35. When the valve is open, water is sucked in from a salt water feed 31 under the influence of the subatmospheric pressure in the reduced-pressure space 41. In the process, the water which has been sucked in flows through a heat exchanger 34, and in the process

is heated by heat which is made available in the cooler 7. The heat for this purpose is transferred in a known way with the aid of a circulation pump 33. Since with salt water being supplied into the receptacle 38 and the water being evaporated, the salt content in the receptacle 38 would increase excessively, water is periodically pumped out of the receptacle 38 using a discharge pump 39.

Figure 3 shows a wind turbine 1 in which the process as described above in connection with Figure 1 can be carried out. The wind turbine 1 is constructed, inter alia, from a tower 52 on which there is a machine housing 48 which can rotate about a vertical axis with the aid of a bearing 49. A compressor 3 is arranged in the machine housing 48. Vanes 45 can rotate about a horizontal axis 2, are mounted in bearings 46 and drive the compressor 3. A direction-change drive 47 for directing the vanes 45 so as to face the wind is likewise arranged in the machine housing 48. A heat exchanger 6 is placed on the machine housing 48 and is used to dissipate heat taken up in the cooler 7 through the air stream 5. On account of the fact that the vanes 45, during use, are directed so as to face the wind by the direction-changing drive 47, there is always a sufficient flow of air 5 through the heat exchanger 6.

Beneath the machine housing 48 is secured a support 50 beneath which is secured a shell 60. Air can flow through the inside of the shell 60 via the feed openings 16 which are present around the wall of the tower 52. In this case, a shielding plate 51 is secured to the support 50, ensuring that only those openings 16 which face the wind direction are open. The result of this is that a slight superatmospheric pressure prevails at the top of the shell 51.

The evaporator 12 is secured to the inner side of the shell 60, with the air-control valve 14 being

positioned on the entry side of the shell 60. The air flowing through the evaporator 12 will be cooled, and as a result the water vapour present in the air will condense. To collect the condensed water, a collection receptacle 55 is positioned beneath the evaporator 12. The cooled air will flow sideways as a flow of air 53 through the air-discharge openings 19 in the wall of the tower 52 and into the environment. The air-discharge openings 19 are shielded by guide plates 54 on the inner side of the tower 52. The cooling and heating elements of the optionally present heat exchanger 59 (not shown) may be respectively arranged at the top of the shell 60 and around the underside of the shell 60.

In the embodiment shown, the control of the wind turbine 1 is not illustrated. On account of the fact that most components are arranged in the machine housing 48, the latter can be of simple design and the control unit may, for example, be of completely mechanical design, in which case the direction-change drive 47 may comprise a weather vane. In another embodiment (not shown), the wind turbine 1 may be provided with a small generator, which is used to top up storage batteries and keep them under voltage, and in this case the control is predominantly electronic. In this case too, stand-alone operation is readily possible. Of course, it is also possible for the device to be connected in a known way to a mains power supply, which may have a low capacity.

Figure 4 shows a wind turbine 1 in which the process as described above in connection with Figure 2 can be carried out. The wind turbine 1 is constructed in a similar manner to that described in Figure 3. The compressor 3 arranged in the machine housing 48 is connected, by means of a set of lines 56 and via a coupling point 57, to the condensation tank 8 positioned in the bottom of the tower 52 and the

reduced-pressure space 41 is connected to the evaporator 12. As an alternative to a set of lines 56, it is also possible to use lines with a rotatable coupling, allowing the machine housing 48 to rotate without limitation with respect to the tower 42. In the example shown, the cooler 7 is designed as a helical line which is positioned in the water 37 in the receptacle 38. The receptacle 38 is provided with a discharge 58 for discharging water which has become too salty, and the receptacle 38 can be filled via the intake line 32. The receptacle 38 is separated, via an elevated central part 61, from the air-control valve 14 and the evaporator 12 positioned beneath it. The condensate 20 which has been collected beneath the evaporator 12 can be discharged via the water discharge 22. The various components required for the process are not all shown, since the person skilled in the art will be aware of how they can be positioned. In one possible embodiment, the vacuum pump 42 is coupled to the wind turbine 1, so that no additional drive is required for this purpose.

Figure 5 shows an alternative to the pressure-control valve 10 and the restriction 11. In this embodiment, it is not necessary for there to be a coupling to the turbine 1, since control is carried out exclusively on the basis of the flow of the refrigerant through the refrigerating-liquid line 9 from the condensation tank 8 to the evaporator 12. For this purpose, a control valve 80 is positioned in the refrigerating-liquid line 9 between the condensation tank 8 and the evaporator 12, as described in the exemplary embodiments discussed above. The condensation tank 8 is connected to a condensation tank connection A and the evaporator 12 is connected to an evaporator connection B.

Figure 5 shows the control valve 80 as comprising two parts, namely a sensor 61 and a pressure-reducing valve 66. In practice, the sensor 61 and the pressure-

reducing valve 66 will generally be assembled within a single housing, in which case the various passages are formed as bores in the housing.

The sensor 61 has a passage 60 with a narrowing 76, which is designed in such a manner that in the event of liquid or gas flowing through the passage 60 at the location of the narrowing, a higher flow velocity is produced, with the result that a lower pressure occurs there. At the location of the narrowing 76 there are one or more bores 62, with the result that the pressure prevailing in a chamber 75 is the same as in the narrowing 76. The flow in passage 60, downstream of the narrowing 76, via a line 63 is passed to a chamber 70 of the pressure-reducing valve 66. The first chamber 75 is connected via a passage 74 to a second chamber 73 of the pressure-reducing valve 66.

The pressure-reducing valve 66 has a cylindrical spring chamber 65 in which a piston 69 can move in a sealing manner. The piston 69 is connected, by way of a piston rod 71, to a diaphragm 72, and the length of the piston rod 71 is matched to a wall of the second chamber 73. The diaphragm 72 is on one side subject to the pressure in the first chamber 70 and on the other side subject to the pressure in the second chamber 73, and the force exerted on the piston 69 by the diaphragm is dependent on the pressure difference between the passage 60 and the narrowing 76. As the flow velocity through the sensor 61 increases, the diaphragm 72 will exert an increasing force on the piston 69.

The dimensions of the piston 69 are such that it closes off an opening 68 when the piston 69 is pressed towards the diaphragm 72 by a spring 64.

As the pressure in the first chamber 70 increases, the piston 69 will move in the direction of the spring 64, so that the opening 68 is partially opened up. As a

result, liquid or gas will start to flow through the opening 68 towards the evaporator 12. The force of the spring 64 and the dimensions of the piston 69 determine, inter alia, the pressure at which the flow will start and therefore also at which the minimum pressure will be present in the condensation tank 9. When the flow to the evaporator 12 starts, a pressure difference will occur between the first chamber 70 and the second chamber 73, and the force on the diaphragm 72 will boost the force of the spring 64. As a result, the pressure in the first chamber 70 and also in the condensation tank 9 will rise. The result of this is that as the flow to the evaporator 12 increases, the pressure in the condensation tank 9 and therefore also at the compressor 3 rises without a further electrical or electronic control means being required for this purpose.

Claims

1. Device for condensing water vapour, having a compressor (3) for compressing refrigerant, a turbine (1) coupled to the compressor, a cooler (7) for cooling the compressed refrigerant, a condensation tank (8) for storing the refrigerant which has been condensed after cooling, an evaporator (12) for evaporating the condensed refrigerant, with refrigerant lines (9) connecting the compressor, the cooler, the condensation tank and the evaporator, a pressure-reducing valve (10; 66) in the refrigerant line between the condensation tank and the evaporator, and a passage (13) for transporting the water vapour which is to be condensed to the evaporator, characterized in that there are first control means (10, 11; 80) for increasing the pressure in the condensation tank as the flow of refrigerant to the evaporator (12) increases, and second control means (14, 17, 18) for controlling the quantity of water vapour transported through the passage (13) to the evaporator as a function of the temperature of the evaporator (12).

2. Device according to Claim 1, in which the first control means comprise a first sensor (61) positioned in the refrigerant line (9) for measuring the flow to the evaporator (12).

3. Device according to Claim 2, in which the first sensor (61) is coupled by pressure lines (63, 74) to the pressure-reducing valve (66).

4. Device according to one of the preceding claims, in which the second control means comprise a second sensor (18) and adjustment means (17) coupled to the second sensor for adjusting an air valve (14).

5. Device according to Claim 4, in which the second sensor (18) and the adjustment means (17) are coupled

by a pressure line.

6. Device according to one of the preceding claims, in which there are separating means (23) for separating solids (24) out of condensed water vapour.

7. Device according to one of the preceding claims, in which there is a heat exchanger (59) positioned in the vicinity of the feed opening (16) and an air discharge (19) for cooling the supplied air by transfer of heat to the air which is to be discharged.

8. Device according to one of the preceding claims, in which the passage (13) forms a closed space (41) with an evaporation space above a receptacle (38) which can be filled with water.

9. Device according to Claim 8, in which there are means (7, 34) for transferring heat from the cooler (7) to the water (37) in the receptacle (38).

10. Device according to Claim 8 or 9, in which the machine housing (48) is positioned on a mast (52), and the closed space (41) and the receptacle (38) are positioned in the vicinity of the foot of the mast.

11. Device according to Claim 8, 9 or 10, in which the closed space (41) is held under a subatmospheric pressure by a pump (42), and the pump is driven by the turbine (1).

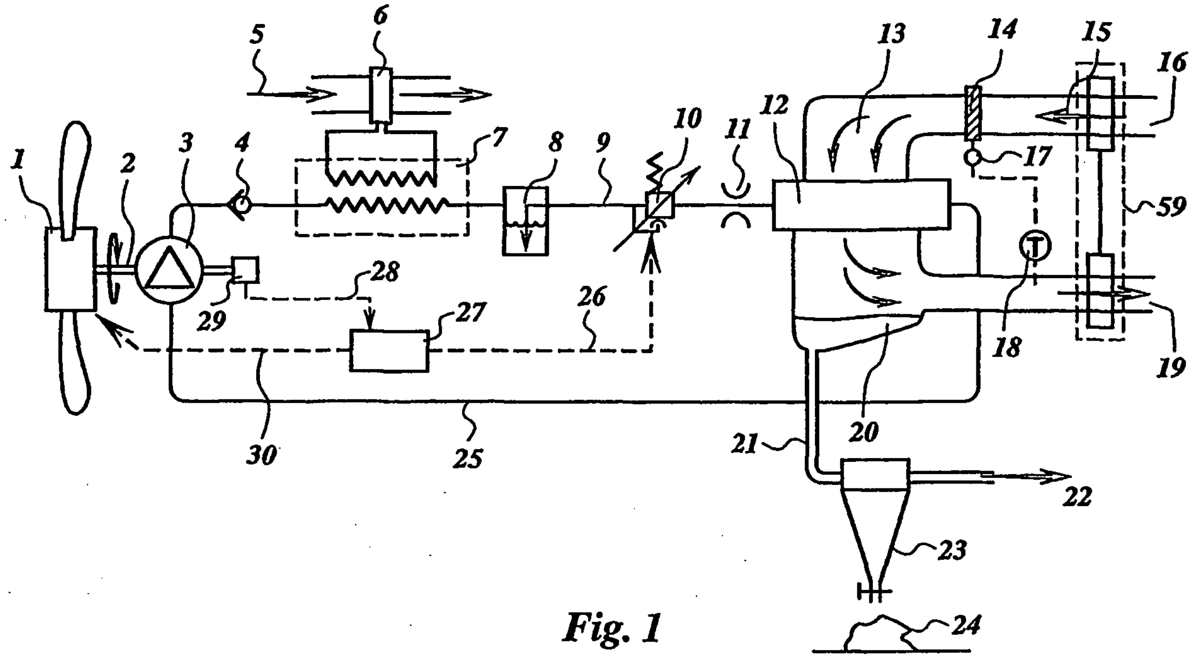

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Fig. 1

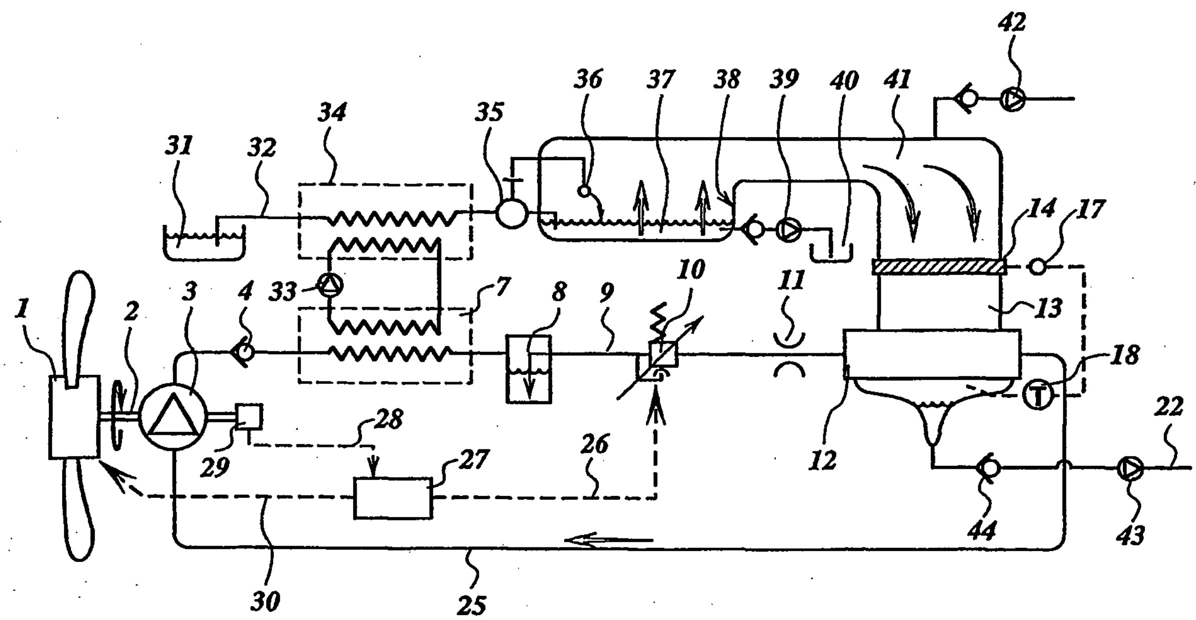
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Fig. 2

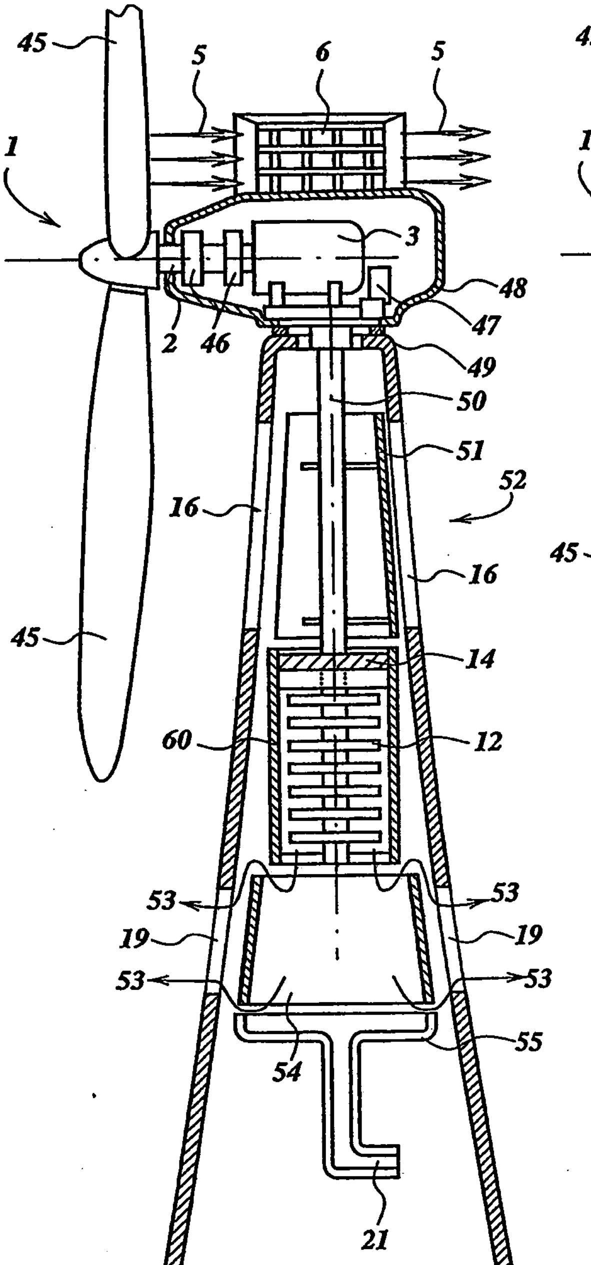
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Fig. 3

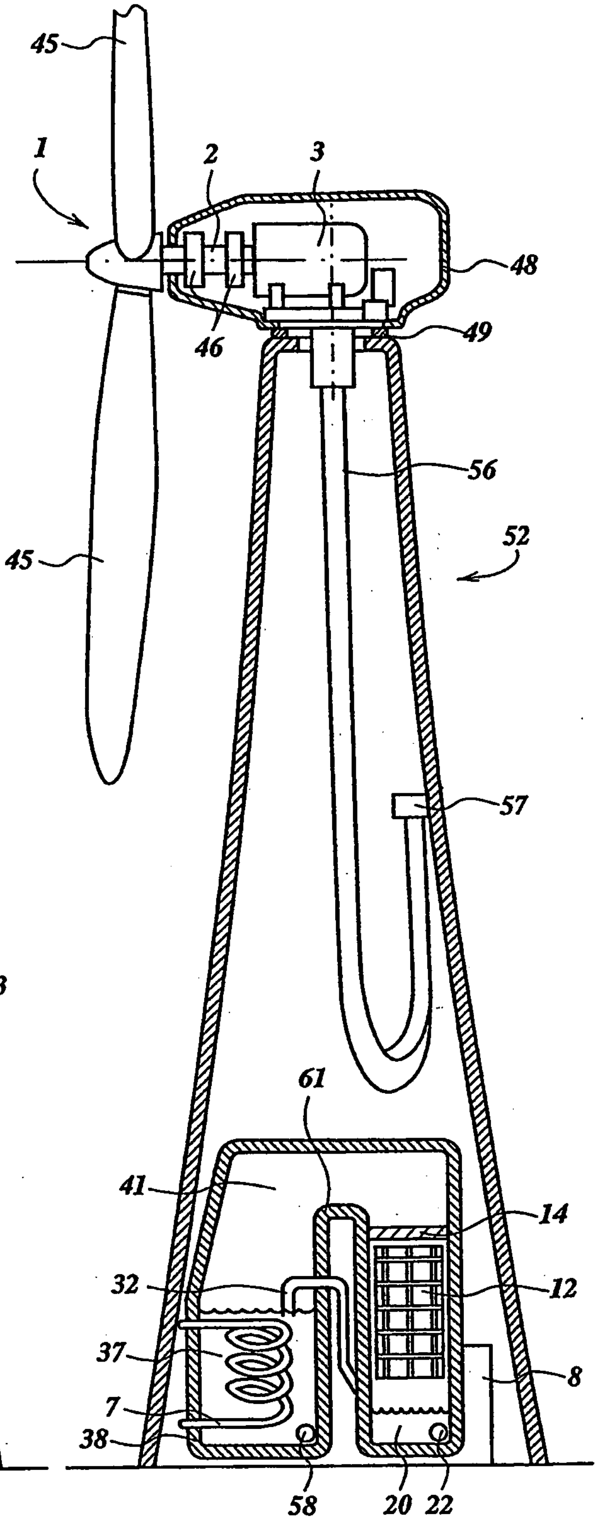
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Fig. 4

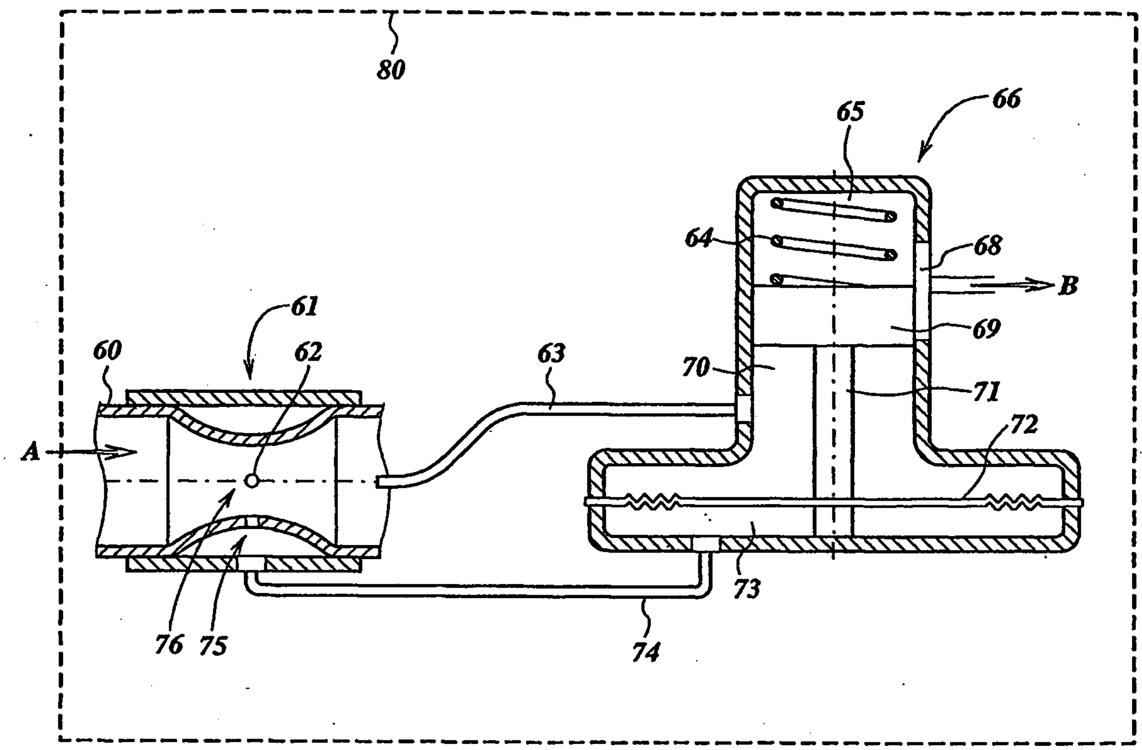

Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No
. . T/NL2004/000322

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F25B27/00 B01D53/26 E03B3/28 F03D9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F25B E03B B01D F24F F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 30 29 985 A (HANSEN UWE) 11 March 1982 (1982-03-11) figure page 4, paragraph 1 page 5, paragraph 1	1-11
Y	US 4 507 932 A (SASAKI MASAYA ET AL) 2 April 1985 (1985-04-02) abstract; figure 4	1-11
Y	WO 01/84066 A (UNIV MARYLAND ;FAWZI HISHAM (US); RADERMACHER REINHARD K (US)) 8 November 2001 (2001-11-08) abstract; figure 1	6,7
Y	JP 53 039973 A (YANAI HIDEO) 12 April 1978 (1978-04-12) figure	8-11

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2004	14/09/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Yousufi, S

Form PCT/ISA/210 (second sheet) (January 2004)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	& DATABASE WPI Section Ch, Week 197821 Derwent Publications Ltd., London, GB; Class D15, AN 1978-37304 abstract	
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